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ALUMINUM-TIN BEARING ALLOYS BY POWDER METALLURGY METHODS

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Nuclear and Powder Metallurgy Section

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ABSTRACT

Powder metallurgy alloys with the same compositions as some cast aluminum-tin bearing alloys (Al-20%Sn, Al-20%Sn-1%Cu and Al-20%Sn-3%Cu) were fabricated from pre-alloyed atomized powder. These alloys had a finer distribution of tin, were stronger with greater fatigue strength, but harder and less ductile than the cast (reticular) bearing alloys.

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INTRODUCTION

Aluminum alloys containing in the order of 20% to 30% Sn with 1% and 3% Cu are attractive for use as bearing material to replace white metal alloys (tin-base and lead-base) and are used by the automobile industry in the United States and Great Britain. These alloys have good wear resistance and high load-carrying capacity, fatigue strength and thermal conductivity. They also have excellent corrosion resistance in lubricating oils[1-5]. Full advantage of the Al-Sn alloys is obtained by bonding them to a steel backing[6,7].

A problem in casting aluminum-tin alloys is that a deterioration in mechanical properties occurs when the tin content is increased above 10%. Tin has a negligible solid solubility in aluminum and there is a wide difference in the melting points of the two metals, so that, on solidification, aluminum grains are enveloped in pure tin. To break up this continuous network of tin and produce what is referred to as a "reticular" structure, it is necessary to cold work and anneal the cast structure of tin-rich alloys.

A possible alternate method of producing aluminum-high-tin alloys with a finely dispersed tin phase is by powder metallurgy techniques using pre-alloyed atomized powder. The rapid cooling during atomization should result in a fine distribution of the tin phase. The object of this investigation is to examine the feasibility and merits of this method.

To date, Al-20%Sn powder metallurgy alloys containing 1% and 3% Cu have been examined; their structures and some physical properties have been compared with those of Al-20%Sn-1%Cu and, Al-20%Sn-3%Cu cast alloys.

EXPERIMENTAL PROCEDURE

Preparation of Alloy Powders

The pre-alloyed powders listed in Table 1 were prepared by alloying aluminum (99.99% purity), tin (99.9% purity) and copper (OFHC) in a silicon carbide crucible coated with china clay and heated in a resistance furnace. Each melt (800 g) was treated with a chlorinated hydrocarbon degassing tablet, skimmed and poured into an apparatus in which the molten alloy was atomized by jets of compressed air. The powder was collected in a water bath then washed in methyl alcohol to minimize any reaction with the water. All powders were air dried and sieved, and the minus 100-mesh fraction was retained for further processing.

Compacting and Extruding

The minus 100-mesh powders were isostatically cold pressed at 10 ksi (69 MN/m^2) into billets 3.2 cm diameter by 6.4 cm long then hot pressed at 200°C (390°F) and 23.5 ksi (162 MN/m^2) for 5 min. Al-20%Sn and Al-20%Sn-1%Cu hot-pressed billets were cooled to 130°C (265°F) and extruded without difficulty into 1.3 cm diameter rod. However, to extrude the Al-20%Sn-3%Cu hot-pressed billets at this temperature, it was necessary to enclose them in 0.3 cm thick pure aluminum cans.

Cast Alloys

For comparison with the powder metallurgy alloys, Al-20%Sn-1%Cu and Al-20%Sn-3%Cu alloys were cast in permanent molds. These alloys were cold worked 20% and annealed at 350°C (660°F) for 1 hr to produce a reticular structure. Some of the Al-20%Sn-3%Cu material was further heat treated for 1 hr at 500°C (930°F), water quenched then aged for 16 hr at 165°C (325°F).

Microexamination

Specimens for microexamination were rough polished on silicon carbide abrasive paper to a 600 grit then with 9-micron, 3-micron and 1/4-micron diamond paste on Metron B cloth, and finally with magnesium oxide on Microcloth.

Mechanical Testing

Room temperature tensile tests, as well as all other tests, were carried out on the alloys in the conditions indicated in Table 2. The tensile specimens were 3.8 cm long with a 1.6 cm gauge length and a 0.4 cm gauge diameter.

Compression tests were carried out on right cylinders 1 cm diameter by 1.3 cm long.

Fatigue specimens were tested on a Krouse High-Speed Rotating Beam testing machine. Specimens had a 0.5 cm gauge diameter and were tested for 5×10^7 cycles.

Vicker's hardness tests were also carried out on the alloys in Table 2.

RESULTS AND DISCUSSION

Microstructure

The microstructures of the extruded powder metallurgy alloys are difficult to resolve using the optical and electron microscopes. However, an electron-scan micrograph in Figure 1 shows the structure of the Al-20%Sn-1%Cu extruded alloy, which can be compared with the "as cast" and reticular structures of a cast alloy of the same composition shown in the photomicrographs in Figures 2 and 3, respectively. The distribution of the tin in the extruded alloy is considerably finer than that shown in the

structures of the cast material, and it is therefore evident that aluminum-high tin alloys with a finely dispersed tin phase can be produced by powder metallurgy techniques. Most of the voids shown in the extruded material are thought to be the result of oxide or tin particles being removed during polishing. This is supported by the fact that the density of the extruded material is 97% that of the cast material, which would not allow as much porosity as is suggested in Figure 1.

The additions of copper to the alloys has no visual effect on the microstructures.

Mechanical Properties

From the data in Table 2 some of the mechanical properties of Al-20%Sn, Al-20%Sn-1%Cu and Al-20%Sn-3%Cu powder metallurgy alloys can be compared with those of the Al-20%Sn-1%Cu reticular, cast alloy which is commonly used for bearings in the automotive industry[5]. In addition, Table 2 lists some properties of an Al-20%Sn-3%Cu reticular, cast alloy which has also been investigated as a possible bearing alloy[1,2]. Properties of this alloy after solution heat treating and ageing are included.

It is evident that all the powder metallurgy alloys have tensile, compression and fatigue strengths superior to the Al-20%Sn-1% Cu and Al-20%Sn-3%Cu reticular, cast alloys. The high fatigue strengths of the powder metallurgy alloys are of particular significance because this is an area where the cast Al-Sn bearing alloys are in close competition with other bearing alloys, and from Table 2 the relatively low fatigue strengths of the cast alloys are apparent.

On the other hand, the powder metallurgy alloys have low ductility and are harder than is ideal for automotive bearings. In fact, because of their hardnesses, these alloys and the heat treated Al-20%Sn-3%Cu cast alloy are more comparable to bronze bearing alloys than to white metal bearing alloys.

Some of the strength and hardness of the powder metallurgy alloys is presumably due to residual cold work after extrusion at 130°C (265°F).

CONCLUSIONS

Extruded Al-20%Sn powder metallurgy alloys containing 1% and 3% Cu have a much finer distribution of tin in their microstructure than reticular, cast alloys with the same compositions. The powder metallurgy alloys are stronger and have considerably greater fatigue strength. Further investigation is intended to increase their ductility and reduce their hardness to values more acceptable in automotive bearing alloys.

ACKNOWLEDGEMENTS

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7. British Patent No. 708472.

TABLE 1

Alloy Powder Compositions, wt %

Nominal Composition	Chemical Composition		
	Sn	Cu	Al
Al-20%Sn	20.67	-	Remainder
Al-20%Sn-1%Cu	19.34	1.00	Remainder
Al-20%Sn-3%Cu	19.80	3.00	Remainder

TABLE 2

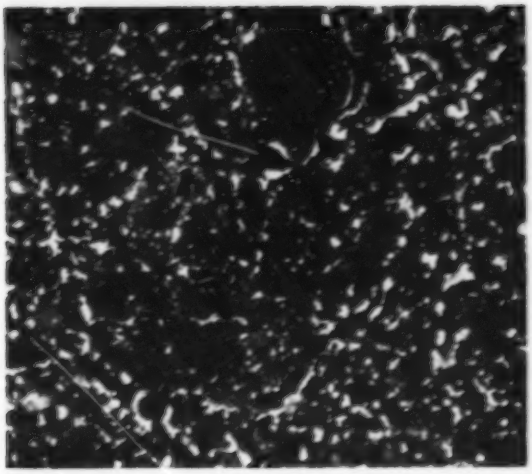
Properties of Alloys

Alloy	Condition	Tensile			Compression ksi (MN/m^2)		VHN 5 kg load	Fatigue psi (MN/m^2) 5×10^7 cycles
		UTS ksi (MN/m^2)	0.2% Y.S. ksi (MN/m^2)	% El 4 $\sqrt{A}$ area	UCS	0.2% Y.S.		
Al-20%Sn	Extruded	28.3 (195)	26.6 (183)	5	N.D.	26.8 (185)	57	6,000 (41)
Al-20%Sn-1%Cu	Extruded	32.8 (226)	30.0 (207)	5	42.0 (290)	29.2 (201)	73	10,000 (69)
Al-20%Sn-3%Cu	Extruded	45.5 (314)	43.5 (300)	3	57.5 (396)	39.8 (274)	84	12,000 (83)
Al-20%Sn-1%Cu	Cast, Reticulated*	16.4 (113)	8.7 (60)	26	N.D.	9.6 (66)	37	<2,000 (<14)
Al-20%Sn-3%Cu	Cast, Reticulated*	18.1 (125)	10.0 (69)	12	N.D.	11.3 (78)	42	<2,000 (<14)
Al-20%Sn-3%Cu	Cast, Reticulated, H.T.**	30.3 (209)	28.4 (196)	3	61.3 (423)	32.6 (225)	82	4,000 (28)

*Cold worked 20% Annealed 350°C (660°F) 1 hr.

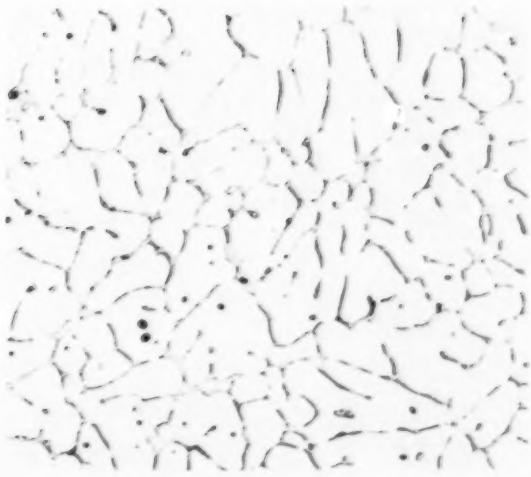
**Cold worked 20%, Annealed 350°C (660°F) 1 hr; Heat Treated 500°C (930°F) 1 hr, water quenched, aged 165°C (325°F) 16 hr.

N.D. - Not Determined.



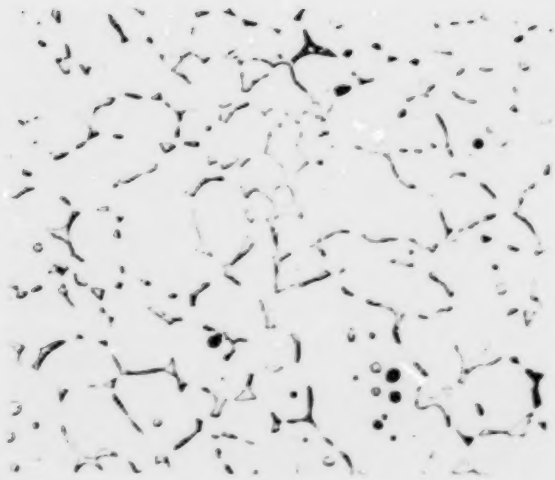
X1150

Figure 1. Al-20%Sn-1%Cu Powder Metallurgy Alloy, Polished, Electron-Scan Micrograph.



X150

Figure 2. Al-20%Sn-1%Cu, As Cast, Polished.



X150

Figure 3. Al-20%Sn-1%Cu, Cast, Reticular Structure.
(Cold Worked 20%, Heat Treated 350°C (660°F) 1 hr), Polished.